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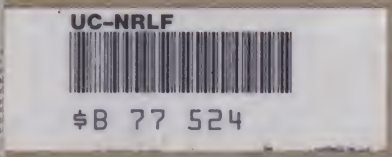

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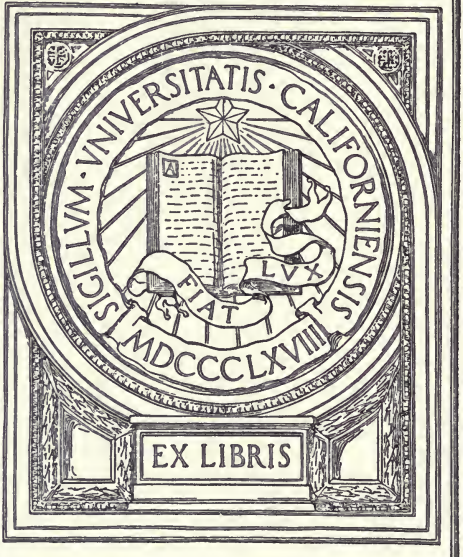

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With compliments of
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The Technical Society of the Pacific Coast.

MEASUREMENT AND FLOW OF WATER IN DITCHES.

BY

AUG. J. BOWIE, JR., M. TECH. SOC.

GIFT

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TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

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MEASUREMENT AND FLOW OF WATER IN DITCHES.

By AUG. J. BOWIE, JR., M. Tech. Soc.

Read June 6, 1884.

In California, where the rainfall over large portions of the State is small and periods of drought of not uncommon occurrence, the development of the agricultural as well as the mining interests, necessarily resulting from the continued influx of population, will be dependent greatly upon the careful husbanding of the water supply. The sources of this supply are comparatively limited, and the problem of systematic irrigation will grow daily in importance from the necessities of the farmers; and the demand for water will steadily increase with the more extended cultivation of the soil.

The costs of construction and maintenance of the necessary canals and ditches (depending principally on their capacity) will be of prime importance to the owners, who will appreciate fully the value of a correct determination of the flow of water. The easy-going farmer who purchases the water, will ultimately discover the necessity of knowing how much he is receiving, and then will come the demand for a standard of measurement of water.

The history of northern Italy, from the fourteenth to the eighteenth century, is replete with accounts of disputes and difficulties arising from the non-existence of some accepted standard of measurement of water. Similar troubles have arisen at times in the mining regions of this country, as can be attested by numerous court reports.

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With the experiences of the past, and in consideration of the future interests of the country, it would seem advisable that some uniform gauge and standard of measurement of water should be adopted.

The miner's inch has only led to confusion and is the relict of the Mexican and Spaniard, who possibly took it from the Italian. Like the Italian oncia, which varied in nearly every province, so its brother the miner's inch has followed suit to even varying in the same district.

In the construction of the various water supply systems for the different placer regions in this State, certain experience in the measurement and flow of water has been acquired, and it has been considered of sufficient import to place some of the results of this work on record, with a view of assisting in clearing up the confusion about the *Miner's Inch,* and giving to those interested in the profession the benefits derived from the several works.

The Miner's Inch.—The Miner's Inch of water is a quantity which varies in almost every district in the State; no one gauge has been uniformly adopted, nor has any established pressure been agreed on, under which the water shall be measured. In some counties there are 10, 11 or 12-hour inches, and in others there is a 24-hour inch. The apertures through which the water is measured are generally rectangular, but vary greatly in width and length, being from 1 inch to 12 inches wide and from a few inches to several feet long. The discharges are through 1′, 1½′, 2′, and 3-inch planks, with square or with square and chamfered edges, combined or not, as the case may be. The bottoms of the openings are sometimes flush with the bottoms of the boxes, sometimes raised above them. The head may denote the distance above the center of the aperture, or again that above the top, and varies from 4½ inches to 12 inches above the center of the aperture.

The Smartsville inch is calculated from a discharge through a four-inch orifice with a seven-inch board top; that is to say, the head is seven inches above the opening, or nine inches above the center. The bottom of the aperture is on a level with the bottom of the box, and the board which regulates the pressure is a plank one inch thick and seven inches deep. Thus, an opening 250

inches long and four inches wide, with a pressure of seven inches above the top of the orifice, will discharge 1000 Smartsville miner's inches. Each square inch of the opening will discharge 1.76 cubic feet per minute, which approximates the discharge per inch of a two-inch orifice through a three-inch plank with a head of nine inches above the center of the opening, the said discharge being 1.78 cubic feet per minute. The Smartsville miner's inch will discharge 2534.40 cubic feet in twenty-four hours, though in that district the inch is only reckoned for eleven hours.

Other Inches.—The miner's inch of the Park Canal and Mining Company, in El Dorado County, discharges 1.39* cubic feet of water per minute. The inch of the South Yuba Canal Company is computed from a discharge through a two-inch aperture, over a one and one-half inch plank, with a head of six inches above the center of the orifice.

At the North Bloomfield, Milton and La Grange mines, the inch has been calculated from a discharge through an opening fifty inches long and two inches wide, through a three-inch plank (outer inch chamfered), with the water seven inches above the center of the opening.

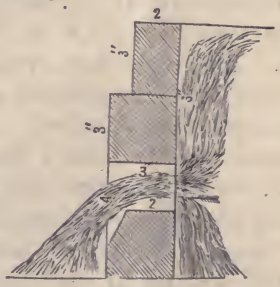

FIG. 1.

Determination of the inch experiments at Columbia Hill.—To determine the value of this miner's inch, a series of experiments was made at Columbia Hill, latitude 39 N., elevation 2900 feet above the sea-level. The *module* used was a rectangular slit fifty inches long and two inches wide; head seven inches above the center of the opening. The discharge was over a three-inch plank; the outer inch chamfered, as shown in Fig. 1.

*Estimated by J. J. Crawford, M. E.

The size of the opening was taken with a measure (micrometer attached), which had been compared with and adjusted to a standard United States Yard. Time was read to one-fifth of a second; the level of the water (drawn from a large reservoir) was determined with Boyden's hook, micrometer adjustment. The following results were obtained:

One Miner's Inch will discharge in one sec.....				.026	cub. ft.
"	"	"	" min....	1.57	"
"	"	"	" hour...	94.2	"
"	"	"	in 24 hours..	2260.8	"

The coëfficient of efflux is 61.6 %. These figures are within the limit of $\frac{1}{50}$ possible error*.

As the two-inch aperture requires too much space for gauging large quantities of water, custom has changed the form of the module, and an aperture twelve inches high by twelve and three-quarters inches wide, through a one and one-half inch plank, with a head of six inches above the top of the discharge, is now used. These openings discharge what is accepted as 200 miner's inches.

A series of experiments was made at La Grange, Stanislaus County, California, latitude 37° 41′ N., elevation 216 feet above the level of the sea, to determine the value of the inch thus delivered in the claims. The results here given are the mean of a series of gaugings taken from nine different apertures, discharging in the aggregate 1,800 miners' inches.

The water was drawn directly from a flume and discharged into a small reservoir, across the lower end of which was fitted a gauge. The velocity of the water issuing from the flume was broken by several drops as it entered the reservoir, and the gauge at the lower end was raised sufficiently to prevent any flow due to an increased velocity which might have been acquired in the flume.

The level of the water was determined with a Boyden's hook.

The discharge from the module was caught in a flume and conducted to a box fitted and leveled for the purpose. Time was read to one-fifth of a second. The following results were obtained:

*The experiments were made in 1874, by H. Smith, Jr., C. E.

1 Miners' inch discharged in	1	second	.02499	cubic feet.
1 " " "	1	minute	1.4994	"
1 " " "	1	hour	89.9640.	"
1 " " "	24	hours	2159.1460	"

Effective coëfficient of efflux, 59.05 per cent.*

An experiment on a single aperture of this form, made by Hamilton Smith, Jr., gave a discharge of 2179.4 cubic feet per miners' inch in twenty-four hours. The 2230 cubic feet of the North Bloomfield inch can only be considered an assumed rough estimate of discharge in 24 hours for 1 miner's inch.

The theoretical velocity in feet per second, of a fluid flowing into the air, through openings in the bottoms or sides of a vessel or reservoir, the surface level of which is kept constantly at the same height, is equal to that which a heavy body would acquire in falling through a space equal to the depth of the opening below the surface of the fluid, and is expressed as follows:

$$v=\sqrt{2gh}.$$

In which v=velocity in feet per second.

g=the acceleration of gravity.

h=the height fallen in feet.

This is called Torricelli's theorem, which supposes indefinitely small orifices with thin sides, and assumes that the upper surface of the water and the orifices are under the same conditions as regards atmospheric pressure. Conditions and size of sectional area of the aperture, friction, resistance of the air to motion and pressure of the atmosphere are all neglected.

The value of g varies in different latitudes, but for all practical purposes is taken as equal to 32.2.

$$\text{The theoretical head}=\frac{v^2}{2g}$$

The acceleration of gravity at latitude 45°=32.17 feet per second, being represented by g, for any other latitude, l.

$$g'=g\ (I-O.\ 002588\ \cos\ 2l)\ \dagger$$

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* The experiments were made by the author.

† See professional papers, Corps of Engineers, U. S. A., No. 12, page 26.

If g represents the acceleration of gravity at the height, h and r the radius of the earth, the acceleration of gravity at the level of the sea equals—

$$g' = g\left(1 + \frac{5h}{4r}\right)$$

Flow of water in open channels.—There is no generally accepted formula for determining the velocity of water in open channels. The tables based on the old formulas published prior to the works of D'Arcy and Bazin, in France, and of Humphreys and Abbot, in the United States, being founded on data which ignore the important factor of the nature of the bed and the sides of the channel, have proved unsatisfactory. Hydraulic engineers have been compelled to rely for correctness of calculated result on the application of a combination of a few known laws with experimental data, which latter, though all important, have been too restricted for the deduction of reliable mathematical theory.

The formulas, in terms of dimensions of cross section and slope, are based upon the supposition of either "permanent" or "uniform" motion. Permanent motion approaches the condition of streams, permits changes of cross section and slope of the water surface, excepting sudden bends, causing eddies and undulations, but demands that the discharge from the different sections should be identical. Uniform motion, in addition, requires an invariable cross section and constant slope of the fluid-surface. The general formulas based on permanent motion, differ from those restricted to uniform motion, "by taking into account changes of living force produced by changes of cross section at the different points."* If these variations are unknown, the difference between the formulas disappears.

Chezy considered that the resistances encountered by water in uniform motion were in direct proportion to the length of the wetted perimeter, to the length of the channel and to the square of the mean velocity, from which he deduced the formula.

---

*Humphreys and Abbot, Mississipi Report, p. 207.

$$v = c\sqrt{rs}.$$

v is the mean velocity in feet per second.
c a coëfficient taken at a constant value.
r the mean hydraulic radius in feet.
s the fall of surface in a unit of length.

The equation indicates the relation of the mean velocity to the slope and the mean hydraulic radius. The value of the coëfficient c has been demonstrated empirically to have a wide range. This formula, however, has been considered the simplest, and has been used by many engineers, different values being given to c, varying from 84 to 100 for large streams, and being as low as 68 for small streams. "Though there is abundant evidence," says Higham (p. 5), "that the latter is much too high for low values of v in earthen channels, and that 100 is too low for very large rivers, as high a value as 254.4 having been deduced from the Mississipi observations."

D'Arcy and Bazin, by their experiments on channels of moderate section with limited variation of grades, proved that the coëfficient c involved not only r and s, but also a constant for the different degrees of roughness of the channel, the formula being applicable within certain limits of inclination and values of r.

Humphreys and Abbot make the velocity vary with the fourth root of the inclination, while Hagen assumes the velocity to vary with the sixth root.

Ganguillet and Kutter considered that the Chezy formula, $v = c\sqrt{rs}$, was the correct point of departure, but that the coëfficient should be made variable, involving not only r and s, but likewise the degree of roughness in the bed or channel.

Ditches in California.—In the mining districts of California ditches are constructed boldly with steep grades and on irregular lines with numerous sharp curves. The cross sections, originally uniform, become more or less varied. Absorption, percolation, evaporation and leakage, reduce the flow. A distinct reliable factor for each of these sources of loss cannot well be incorporated in the coëfficient of discharge. If, then, it is intended to cover all of these common sources of loss by such

a coëfficient, its value must be a material modification of values given commonly in the text books. It would be certainly an affectation of accuracy to apply so complicated a formula as that of Kutter in such a case, since the modifying conditions which can be estimated but roughly, call for a large reduction of the calculated result. This will be apparent from the measurements of discharge given further on. The simple formula, $Q=ac\sqrt{rs}$, expresses more fitly the result of experience in such cases, wherein—

Q—Is the quantity of water which the ditch is capable of carrying in cubic feet per second?

a—The effective area of cross section of ditch as constructed originally, in square feet.

r—The hydraulic mean depth in feet.

s—The fall of surface in a unit of length.

c—A coëfficient covering all common losses.

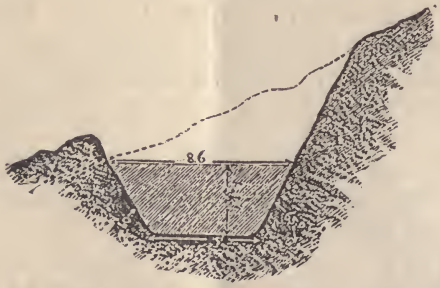

FIG. 2.—*North Bloomfield Main Ditch.*

Examples of value of Coëfficient in Ditches.—In its application to the North Bloomfield Main Ditch,* (length 40 miles, sectional area 23.89 square feet, grade 16 feet per mile) with its abrupt turns and sinuous course, the value of the coëfficient *c*, as determined, varies from 44.7 to 37.7 in accordance with the season of the year.

The Texas Creek† branch ditch is about seven-tenths of a

*Increase capacity of this ditch is limited by the pipes across Humbug Cañon.

†For details of Texas Creek ditch and flume, see paper by Hamilton Smith Jr., Transactions Am. Soc. C. E., Vol. XIII, pp. 30–31.

mile long. Its sectional area is 13.5 feet and the grade is 20 feet per mile. The sides are rough and the curves are sharp. With a flow of 32.8 cubic feet per second, the ditch runs about full. The value of c=33. In connection with this ditch there is a rectangular flume 2′.67 wide x 2′.83 deep, made of unplaned boards, set on a grade of 32 feet per mile. The flume has some sharp but regular curves, and the water from the ditch runs it nearly full at these points. With the discharge 32.8 cubic feet per second, c=59.

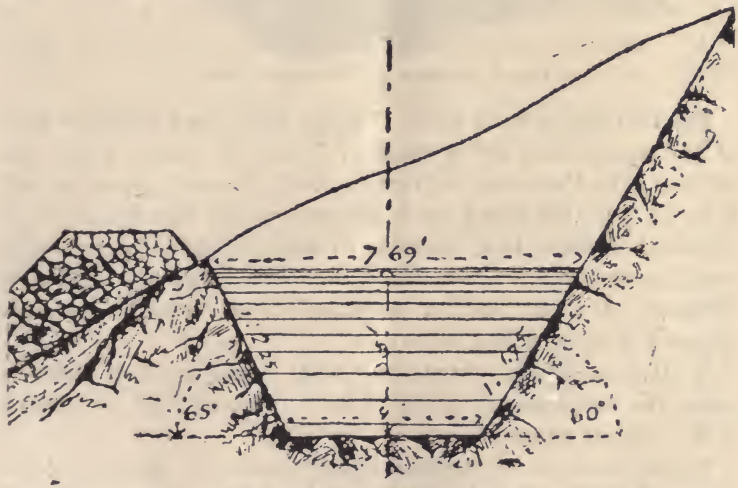

FIG. 3.—*Section of Milton Ditch.*

On the Milton line, from Milton to Eureka, a distance of 19.4 miles, the sectional area of the ditch is 20.39 square feet, grade 19.2 feet per mile for the earthwork and 32 feet per mile for flume. The line is very irregular, having many drops and chutes. The distance from Milton to the measuring box at Bloody Run is 29½ miles. The minimum established grade for the last 10.1 miles was 16 feet per mile, with a sectional area for the ditch of 23.05 square feet. The coëfficient c determined from the gauging at the measuring box has varied from 22 in its leakiest condition to 31, which latter can be taken as correct for the present condition. In the succeeding 30 miles below the

gauge, owing to a better character of ground, the coëfficient reaches 41.

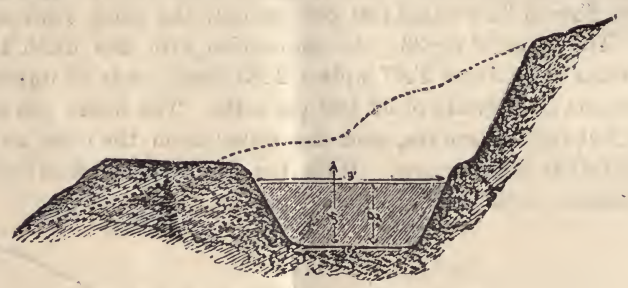

FIG. 4.—*Section of La Grange Ditch.*

The La Grange main ditch, 17 miles long, has a sectional area of 22.5 square feet, and a slope of 7 feet per mile. From the delivery at its Patricksville junction the coëfficient c is determined to be 52, but it is based upon the assumption that the depth of the canal is three feet, whereas in the original construction it was supposed to have been made four feet deep, the discharge therefore due to such a sectional area, would diminish necessarily the ascribed value of c*.

In all these canals, after the artificial banks are well consolidated, the water area is increased beyond the original excavation in the natural ground.

Accuracy cannot be expected in calculating the values of Q for proposed ditches of such character. Important losses must vary in every ditch, depending on the nature of the ground, and the character of the construction of the work and the season of the year. The feeders along the lines compensate largely for these losses. In order to be safe in estimating the capacity of a ditch, the value of the coëfficient c for the dry season should be taken.

The following facts show the magnitude of the losses due to absorption, leakage, evaporation, etc.:

Three thousand miners' inches of water (a flow of 75 cubic feet per second) turned in during the dry season at the head of the

*The grades given in all the above cases, from which the different values of C were calculated, exclude the drops, chutes, flumes, etc. Sectional areas represent minimum cross-sections.

Bloomfield ditch, will deliver 2700 inches (67.5 cubic feet per second) at the gauge 40 miles distant. Twenty-four hundred inches of water (60 cubic feet per second) turned in at the head of the Milton ditch delivered formerly at the gauge, 29½ miles distant, 1450 to 1600 inches (36.25 to 40 cubic feet per second), but at present 2500 inches (62.5 cubic feet per second) turned into the head of the ditch, delivers 2000 inches (50 cubic feet per second) at the gauge. The exact loss of water between the head of this ditch and the measuring box is shown in the following summary, taken from the official records for the month of August for the years 1875 to 1882, inclusive. This month is taken as a dry month, as prior to that time the numerous side streams swell the amount delivered at the gauge.

RECORD FOR AUGUST.

Year.	Water turned at Milton, 24 hours, inches.	Water record at Bloody Run, 24 hours, inches.	Per cent.
1875	44,000	34,950	79.4
1876	59,700	42,625	71.3
1877	67,875	44,700	65.9
1878	76,050	58,875	77.4
1879	82,725	51,350	62.0
1880	74,080	55,325	74.7
1881	66,850	48,325	72.3
1882	68,300	50,984	74.4

The Eureka Lake ditch, with 2500 inches turned in at the head, delivers at the gauge, thirty-three miles distant, about 1800 inches in the dry season.

The above statistics lead to the adoption of values of the coefficient c, varying from 31 to 45, in estimating the capacity of ditches on heavy grades of forty miles length flowing from sixty to eighty cubic feet per second, such as referred to—that is:

$$Q = 31 \text{ to } 45\ a\ \sqrt{rs}.$$

The loss incurred in the distribution of water is denoted by the following figures, taken from the official records of two mining companies. The amount received is measured, at or near the distributing reservoirs; the amount used, at or near the pres-

sure boxes. The difference shows the losses from leakage, evaporation, absorption, and wastage arising from excess of constant supply over the amount needed, with interruptions at the claim.

NORTH BLOOMFIELD COMPANY (24 HOUR INCHES).

Year.	Amount Received.	Amount Used.	Loss.
1870 to 1879, inc..	5,838,865	5,504,758	334,107 = 6 per cent.
1880..... ..	945,550	920,612	24,938 = 2½ "
1881*.....	950,340	866,962	83,378 = 9 "
1882.....	1,025,880	1,005,977	19,903 = 2 "
1883.....	862,660	836,251	26,409 = 3 "
14 years.....	9,623,295	9,134,560	488,735 = 5 per cent.

MILTON COMPANY (24 HOUR INCHES).

1882.....	685,933	635,884	50,049 = 7 per cent.
1883†.....	446,224	361,877	84,347 = 19 "
2 years.....	1,132,157	907,761	134,396 = 13 per cent.

*Much water run to waste during 4 months, owing to cessation of work caused by litigation.

†English reservoir was destroyed June 18, 1883, from which source the main water supply was obtained.

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